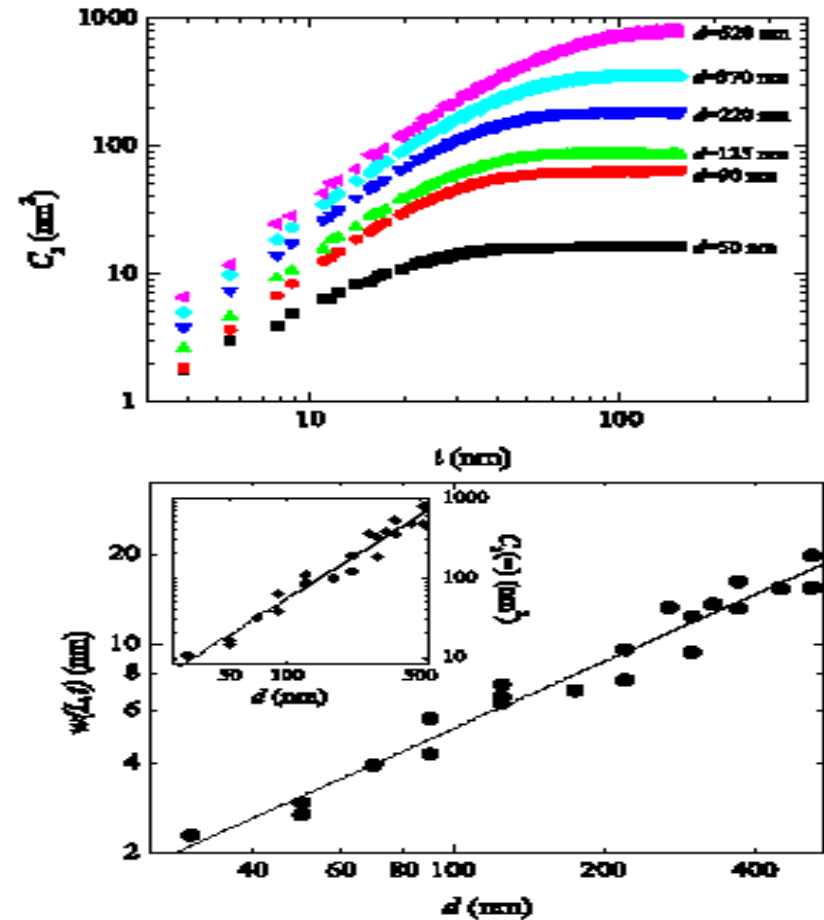


# Evidence for Power-Law Dominated Noise in Vacuum Deposited $\text{CaF}_2$

R.B. Hallock, University of Massachusetts, DMR-0138009

The roughness of a surface originates through small random perturbations that occur during the growth process, i.e., through the presence of noise. In many instances this noise has been assumed to be Gaussian and uncorrelated, which led to the establishment of universality classes, each characterized by a set of exponents. It was later shown theoretically that if the noise follows a power-law distribution, the critical exponents are different, resulting in non-universal behavior. Our AFM work with a sequence of rough  $\text{CaF}_2$  surfaces shows clear evidence for such power-law distributed noise in  $2 + 1$  dimensions.

D.R. Luhman and R.B. Hallock,  
Phys. Rev. Letters, June, 2004



The top figure shows the second moment of the surface roughness,  $C_2$ , the slope of which yields the roughness exponent  $\alpha$ . The second figure shows the interface width,  $W$ , and the inset shows  $C_2(\infty)$ , the slopes of which yield the growth exponent,  $\beta$ . We find  $\alpha = 0.88$  and  $\beta = 0.75$ .

Almost all surfaces that exist in nature are rough on some distance scale. The bark of a tree is very rough on a distance scale of inches and fractions of an inch, the surface of the earth is rough on distance scales from inches to many miles, and the surfaces of even smooth-looking things (like glass or the paint on a car) are rough on the scale of very small distances. Some surfaces are grown by industrial processes and the manner in which the growth takes place is of fundamental as well as practical interest. A natural consequence of the growth of such surfaces is the presence of noise in the growth process, noise that limits the ability to create a smooth surface or influences the character of the roughness in situations where roughness is desirable. The work that we have carried out shows that a specific type of roughness that previously was only predicted theoretically actually exists in nature and it has been characterized. It remains to be seen how robust this type of roughness growth is (other materials and manners of surface preparation have to be tried), whether this new understanding will help us to create smoother surfaces or surfaces of tailored roughness in the future, or what the relevance might be to improving the quality or efficiency of industrial surface preparation processes.

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## Education:

This work began with the work of graduate student Justin Herrmann, who studied the behavior of third sound (waves on helium films) in the presence of surface disorder created by the deposition of  $\text{CaF}_2$ . A new graduate student Dwight Luhman sought to characterize the disorder introduced by the  $\text{CaF}_2$  and in so doing came to the unexpected conclusion that the surface roughness is consistent with power-law dominated growth. Dwight is assisted by an undergraduate physics major, Kyle Thompson who is extending this work to study the growth of  $\text{CaF}_2$  films on other surfaces, themselves initially smooth or rough and of different materials.

## Societal Impact:

Most surfaces in nature are naturally not smooth and have some degree of roughness. The question of how this roughness comes about for surfaces that are created by vapor deposition has been studied for a number of situations due to its relevance to fundamental understanding and its importance in industrial processes. In many such situations, a smooth surface is the desired goal and an understanding about how roughness originates may help to create smoother surfaces or surfaces with controlled roughness in the future.